

Preference and development of *Tribolium castaneum* (Herbst, 1797) (Coleoptera: Tenebrionidae) in whole grain and flour form of five corn varieties

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Abstract. Astuti LP, Lestari YA, Rachmawati R, Mutala'liah. 2020. Preference and development of *Tribolium castaneum* (Herbst, 1797) (Coleoptera: Tenebrionidae) on whole grain and flour form of five corn varieties. *Biodiversitas* 21: 564-569. Red flour beetle can cause detrimental loss on stored corn during storage period. The usual forms of stored corn are whole grain and flour form. However, the information about the infestation on both form of stored corn is limited, therefore this research aims to investigate the feeding preference and development of *Tribolium castaneum* on various corn varieties (Pioneer 21, Pioneer 29, Pertiwi 3, Bisi 18, and Bisma) in whole grain and flour form. The research was conducted on Plant Pest Laboratory, Department of Plant Pests and Diseases, University of Brawijaya from February until March 2016. The feeds for treatment were Pioneer 21, Pioneer 29, Pertiwi 3, Bisi 18, and Bisma in whole grain and flour form. The observed variables were the adult presence, adult mortality, the number of eggs, larvae, pupae, F1 progeny emerged, the developmental period of eggs, larvae, and pupae, egg-adult, and life cycle. Data analyzed by ANOVA and followed by LSD at 5%. The results showed that *T. castaneum* was more preferred to colonize and oviposition in Pioneer 21 flour than others i.e. 13.33 adults and 145 eggs. Similarly, on the population growth of *T. castaneum*, the highest number of eggs, larvae, pupae, and F1 progeny emerged was on Pioneer 21 flour i.e. 196 eggs, 179.67 larvae, 83.67 pupae, and 73.33 adults, respectively. Moreover, the fastest developmental period of egg, larva, and pupa, egg-adult and life cycle was also in Pioneer 21 flour i.e., 5.5, 26.77, 5.97, 38.23, and 41.87 days, respectively. Pioneer 21 corn variety has high protein content, therefore it is suitable for *T. castaneum* development.

Keywords: Corn varieties, development, preference, red flour beetle

INTRODUCTION

Corn is the second most important commodity after rice in Indonesia. While in the world, it is the third major cereal that cultivated after wheat and rice. It is originated from South and Central America (Oladejo and Adetunji 2012). Corn can be used as food (48.4%), feed (38.3%), industrial materials (6.2%), and seeds (1.2%) (Swastika et al. 2004). In Indonesia, corn is one of the staple food which has rich starch content, vitamins, proteins, and mineral (Khawar et al. 2007). The need for corn as food and feed is increasing by the year along with Indonesian population growth. Based on Statistics Indonesia (2019), corn production in 2015 was 20.67 million tons of dry shelled and increased by 1.66 million tons (8.72%) than in 2014. Another increasing was happened in Indonesian feed mills at about 3.2% from 24.7 to 25.5 million tons in 2018 (McDonald and Meylinah 2019). The escalation of corn production must be followed by appropriate postharvest handling activities. Due to the corn production demand, there are many varieties of corn that are traded in Indonesia, such as Pioneer 21, Pioneer 29, Pertiwi 3, Bisi 18, and Bisma.

The vulnerable period of stored product is during the storage that can cause detrimental loss in both quantity and quality. Pest attacking stored products can cause 20-30% losses in tropical countries (Suleiman and Kurt 2015). Red flour beetle, *Tribolium castaneum* (Herbst, 1797)

(Coleoptera: Tenebrionidae) is one of the stored product pests that can cause losses a wide range of durable stored products including barley, corn, flour, millet, wheat, potatoes, sweet potatoes, dried fruit, nut, and sorghum (Bennet 2003). This species is an important and cosmopolitan insect pest on grain processing and storage (Fedina and Lewis 2007). *T. castaneum* can be a major pest on flour mills, stored biscuit industry, and retail stores (Campbell and Hagstrum 2002). This pest causes more serious damage to the processed cereals in the form of flour rather than whole-grain (Zakka et al. 2013). The infestation of this insect cause unpleasant smell due to the benzoquinone secretion from its abdominal gland (Campbell and Runnion 2003).

Information on *T. castaneum* that attack corn varieties in the form of whole grain is limited, because of this pest generally feeds on broken grain as a secondary attack resulting from another pest. Even though, the stored corn is not only stored in the form of whole-grain but also flour form. Furthermore, each corn varieties has different nutrition content and hardness level that could be the influence factor of its resistance. Hence, this research aimed to examine the preference, population growth, and development of *T. castaneum* on various varieties of corn, i.e., Pioneer 21, Pioneer 29, Pertiwi 3, Bisi 18, and Bisma in the form of whole grain and flour.

MATERIALS AND METHODS

This research was conducted in Plant Pest Laboratory, Department Plant Pests and Diseases, Faculty of Agriculture, University of Brawijaya under laboratory condition ($27 \pm 2^\circ\text{C}$, RH $65 \pm 5\%$). *T. castaneum* were obtained from the warehouse in the market and have been reared in the laboratory for two generations. These insects were re-reared on separate glass jar for about a month that will be used for treatment. One hundred unsexed *T. castaneum* adults were put in glass jar ($\varnothing = 15$ cm, $t = 17$ cm) containing mix of wheat flour and: baker's yeast at a ratio (95%: 5%) for 7 days. Yeast addition on the feed was aimed to enrich the nutrition content of feed. Sex differentiate was carried on the pupae stage by distinguishing genital papillae of insects (Beeman et al. 2019), then insect rearing was continued in a different glass jar until adults emerged. Tested adult insects used on this treatment were 7-14 days old (Heinrichs et al.1985). Proximate analysis and hardness levels of feed were done to support the results research.

Research was consist of two experiments: (i) preference (ii) population growth and development of *T. castaneum* on five corn varieties in whole grain and flour form. These research used ten treatments (Pioneer 21 whole grain, Pioneer 29 whole grain, Pertiwi 3 whole grain, Bisi 18 whole grain, Bisma whole grain, Pioneer 21 flour, Pioneer 29 flour, Pertiwi 3 flour, Bisi 18 flour, and Bisma flour) and three replications arranged by Complete Randomized Designed. The preference test was done by free choice test method using preference cage ($\varnothing = 28$ cm, $t = 8$ cm) consist of 10 rooms to investigate feeding and oviposition preference of adult insects. Thirty g of feed was put into each room in the preference cage, and 30 paired of adult insects were infested on the center of preference cage for 7 days and separately taken out depending on the chosen feed. The observed variables were the presence of adult insects and the number of eggs. The eggs laid on feed was taken by 50 mesh sieve. The adult male of *T. castaneum* is characterized by having small sex patches on the first pair of femur (Beeman et al. 2019).

Population growth and development test were done by no choice test method i.e. tested singly on each feed in different glass jar. Fifteen pairs of adult insects were put on the 30 g of feed-in glass jar ($\varnothing = 6.5$ cm, $t = 9$ cm) covered by gauze for 7 days. The observed variables for population growth were adults mortality, the number of eggs, larvae, pupae, and F1 progeny emerged, while for insect development were egg, larva, pupa period, egg-adult, and life cycle of *T. castaneum*. Insect mortality and egg calculation were observed on 7 days after infestation then the feed and eggs were put back into the glass jar to be reared until the larvae, pupae, and F1 progeny emerged. Larvae and pupae of *T. castaneum* were observed on 14 and 28 days after infestation, respectively (Kayode et al. 2014). The observation of F1 progeny emerged was carried on every day since the first emerged until no more adults appeared. Egg-adult period was determined by calculating total development time of *T. castaneum* from egg until F1 progeny emerged, while life cycle was determined by

calculating insect longevity and first oviposition time. Data were analyzed using analysis of variance (ANOVA) at 5% and followed by least significant different (LSD) test at 5% for further analyses. Analysis of data used R 3.5.2 software.

RESULTS AND DISCUSSION

Colonization and oviposition preference of *Tribolium castaneum* on five corn varieties

Insect preference had a certain response to the type and form of feed that can optimally support insect growth and development. In general, *T. castaneum* was preferred on flour form than whole grain in the same variety. This was in line with *T. castaneum* feeding behavior, which was categorized as a secondary pest (Rees 2004). Preference of *T. castaneum* both colonization and oviposition preference was significantly influenced by corn variety and form of the feed.

Table 1. Colonization preference of *Tribolium castaneum* on five corn varieties in whole grain and flour form

Treatments	Collonization preference ($\bar{X} \pm$ SE)	
	Female (adult)	Male + female (adult)
Pioneer 21 whole grain	1.00 \pm 0.00a	3.67 \pm 0.19 a
Pioneer 29 whole grain	1.33 \pm 0.19b	2.67 \pm 0.19a
Pertiwi 3 whole grain	1.33 \pm 0.19b	2.67 \pm 0.38a
Bisi 18 whole grain	1.33 \pm 0.19b	3.00 \pm 0.33a
Bisma whole grain	1.33 \pm 0.19b	3.33 \pm 0.38a
Pioneer 21 flour	8.00 \pm 0.00g	13.33 \pm 0.19e
Pioneer 29 flour	4.67 \pm 0.19e	8.33 \pm 0.19c
Pertiwi 3 flour	6.00 \pm 0.00f	10.67 \pm 0.51d
Bisi 18 flour	3.00 \pm 0.33d	6.00 \pm 0.33b
Bisma flour	2.00 \pm 0.33c	6.33 \pm 0.19b

Note: The mean at the same column followed by the same letters are not significantly different ($p < 0.05$)

Table 2. Mean number of *Tribolium castaneum* eggs on five corn varieties in whole grain and flour form in oviposition preference test

Treatments	Mean number of eggs ($\bar{X} \pm$ SE)
Pioneer 21 whole grain	7.67 \pm 1.02a
Pioneer 29 whole grain	6.67 \pm 2.12a
Pertiwi 3 whole grain	5.67 \pm 0.19a
Bisi 18 whole grain	5.33 \pm 0.51a
Bisma whole grain	6.67 \pm 1.26a
Pioneer 21 flour	145.00 \pm 14.99d
Pioneer 29 flour	102.67 \pm 4.86c
Pertiwi 3 flour	134.33 \pm 7.07d
Bisi 18 flour	79.00 \pm 4.16bc
Bisma flour	70.33 \pm 5.59b

Note: The mean at the same column followed by the same letters are not significantly different ($p < 0.05$)

Tabel 3. Mortality of *Tribolium castaneum* adults on five corn varieties in whole grain and flour form

Treatments	Adult mortality* (%)
	($\bar{X} \pm SE$)
Pioneer 21 whole grain	1.11 \pm 0.64
Pioneer 29 whole grain	6.67 \pm 1.11
Pertiwi 3 whole grain	4.44 \pm 0.64
Bisi 18 whole grain	10.00 \pm 2.94
Bisma whole grain	5.56 \pm 3.21
Pioneer 21 flour	1.11 \pm 0.64
Pioneer 29 flour	1.11 \pm 0.64
Pertiwi 3 flour	1.11 \pm 0.64
Bisi 18 flour	6.67 \pm 2.22
Bisma flour	2.22 \pm 1.28

Note: * Data was transformed to $\sqrt{x + 0,5}$

Based on the preference test, the mean number of *T. castaneum* adults female presence on Pioneer 21 flour was the highest (eight adults) and significantly different from others (Table 1). In contrast, the mean number of adults female presence on Pioneer 21 whole-grain was the lowest (one adult) and also significantly different than others, whereas the other four varieties i.e. Pioneer 29, Pertiwi 3, Bisi 18, and Bisma in whole grain form were not significantly different i.e. 1.33 adults. Total number of adults (male and female) presence was higher on Pioneer 21 flour (13.33 adults) than others varieties, while the lower presence was on Pioneer 29 and Pertiwi 3 whole grains (2.67 adults) and not significantly different with Bisi 18, Bisma, and Pioneer 21 in whole grain form at about 3.00, 3.33, and 3.67 adults, respectively, but it was significantly different with others (Table 1). The highest number of egg was on Pioneer 21 flour i.e. 145.00 eggs, however, it was not significantly different from Pertiwi 3 variety i.e., 134.33 eggs, but significantly different with others. On the other hand, the lowest number of eggs was on Bisi 18 whole-grain i.e., of 5.33 eggs, which was not significantly different with Pertiwi 3, Bisma, Pioneer 29, and Pioneer 21 varieties of whole-grain at 5.67; 6.67; 6.67; and 7.67 eggs, respectively, but significantly different with others (Table 2). Astuti et al. (2013) stated that the preference of insects is influenced by physical and biochemical of grain. This result showed that *T. castaneum* was more preferred to colonize and oviposition in flour form of all varieties than whole-grain form. This was in line with Turaki et al. (2007), *T. castaneum* is a primary pest on processed grain like flour than other stored product in kernels. This insect was more preferred on flour form than whole grain (Abushama and Jerawi 1987; Zakka et al. 2013). Furthermore, the research results of Rustamani et al. (2014) showed that *T. castaneum* adults were more preferred on wheat flour (77%) than semolina (19%), corn kernels (2%), and biscuit (2%). The colonization preference of *T. castaneum* adults on feed indicates that the feed will be used as a host for copulation and laying eggs. The high number of eggs laid in the feed is related to the number of female adults present on the feed. The number of eggs was higher on Pioneer 21 flour because the present number of *T. castaneum* adult female was also higher on

Pioneer 21. There was a positive correlation between the number of *T. castaneum* adult females present with the number of eggs laid on the feed ($r = 0.943$; $P = 0.01$). The more number of adult females present on the feed, the more eggs laid on the feed.

Population growth and development

The statistical result on adult mortality was not significantly different on five corn varieties both in whole grain and flour form (Table 3). Results on the number of eggs, larvae, pupae, and F1 progeny emerged showed a significant effect on five corn varieties in whole grain and flour form (Table 4).

Table 4 showed that the highest number of eggs was on Pioneer 21 flour at about 196 eggs and not significantly different from Pertiwi 3 flour, but significantly different from others. On the contrary, the lowest number of eggs was on Bisi 18 whole-grain i.e., 11.00 eggs and not significantly different from another whole grain form of Pioneer 29, Pertiwi 3, and Bisma variety. Similarly, the highest number of larvae was on Pioneer 21 flour i.e., 179.67 larvae and the lowest was on Bisi 18 whole-grain which was not significantly different from Pioneer 29, Pertiwi 3, Bisma, and Pioneer 21 in whole grain. The highest number of pupae was on Pioneer 21 flour i.e., 83.67 pupae and not significantly different from Pertiwi 3 flour, while it was significantly different from others. The lowest number of pupae were found on Bisi 18 whole grain, and Pioneer 29, also were not significantly different from Pertiwi 3, Bisma, and Pioneer 21. The number of pupae result was as well as the number of F1 progeny emerged. The higher was on Pioneer 21 flour and not significantly different from Pertiwi 3 flour i.e. 73.33 and 64.00 adults, but it was significantly different from others. F1 progeny emerged on Bisi 18 and Pioneer 21 whole-grain was lower than another whole-grain variety form i.e. 1.00 adults (Table 4).

The developmental period of egg, larva, pupa, egg-adult, and life cycle on five corn varieties in whole grain and flour form showed a significant influence. Egg period of *T. castaneum* was faster on Pioneer 21 flour i.e. 5.5 days and not significantly different from Pioneer 29 flour, Pertiwi 3 flour, and Pioneer 21 whole-grain, i.e. 5.67, 5.50, and 5.70 days, respectively. Egg period was experienced longer on Bisma whole grain at about 6.13 days and not significantly different from whole grain form of Bisi 18, Pertiwi 3, Pioneer 29 and flour form of Bisi 18 and Bisma. (Table 5).

The faster larval period was on Pioneer 21 flour at about 26.77 days and not significantly different from Pertiwi 3 flour at about 27.03 days. The longer period of larva was on Bisi 18 whole-grain i.e. 27.97 days which was not significantly different from other whole grain forms and significantly different from other flour forms. Similar to pupa, the faster period was found on Pioneer 21 flour i.e. 5.97 days which was not significantly different from Pertiwi 3 and Pioneer 29 flour i.e. 6.10 days. The longer period was on Bisma whole-grain i.e. 6.53 days and was not significantly different from all varieties in whole grain form, i.e. 6.43 days (Table 5). Developmental period of *T.*

castaneum (egg-adults) was faster on Pioneer 21 flour at about 38.23 and not significantly different with Pertiwi 3 flour at about 38.63 days. On the contrary, it was longer on Bisma whole-grain, i.e. 40.63 days and not significantly different from Bisi 18 whole-grain, i.e. 40.23 days. Similarly, life cycle of *T. castaneum* experienced faster on Pioneer 21 flour which was not significantly different from Pertiwi 3 and Pioneer 29 flour at about 41.87, 42.73, and 42.77 days, respectively. The longer life cycle was on Bisma whole-grain i.e. 49.13 days and not significantly different from other varieties (Bisi 18, Pertiwi 3, and Pioneer 29) in whole grain form at about 48.57, 48.43, and 48.30 days, respectively (Table 5).

Table 7. The matrix of correlation coefficient between physicochemical characteristics of corn and the number of eggs, larvae, pupae, and F1 progeny emerged of *Tribolium castaneum*

Physicochemical characteristics	Eggs	Larvae	Pupae	F1 progeny emerged
Protein	0.258	0.291	0.363	0.399
Fat	0.005	0.023	0.021	0.014
Ash	0.108	0.094	0.146	0.173
Water	0.164	0.167	0.255	0.163
Carbohydrate	-0.217	-0.235	-0.325	-0.343
Hardness	-0.759*	-0.711*	-0.785*	-0.826*

Note: * show significances

Table 4. Population growth of *Tribolium castaneum* eggs, larvae, pupae, and F1 progeny on five corn varieties in whole grain and flour form

Treatments	Population growth ($\bar{X} \pm SE$)			
	Number of eggs	Number of larvae	Number of pupae	F1 progeny
Pioneer 21 whole grain	25.67 ± 1.71 b	15.00 ± 3.53 a	6.67 ± 1.00 a	5.67 ± 0.51 a
Pioneer 29 whole grain	15.00 ± 3.28 ab	5.33 ± 1.71 a	1.67 ± 0.69 a	1.00 ± 0.33 a
Pertiwi 3 whole grain	15.67 ± 3.20 ab	5.67 ± 1.02 a	2.67 ± 0.69 a	2.33 ± 0.84 a
Bisi 18 whole grain	11.00 ± 0.67 a	3.67 ± 1.71 a	1.67 ± 0.51 a	1.00 ± 0.33 a
Bisma whole grain	28.33 ± 1.84 b	18.33 ± 1.20 a	7.00 ± 0.51 a	4.67 ± 0.51 a
Pioneer 21 flour	196.00 ± 4.41 e	179.67 ± 3.72 e	83.67 ± 16.19 d	73.33 ± 15.08 d
Pioneer 29 flour	137.00 ± 5.86 d	112.33 ± 5.00 c	51.00 ± 1.53 bc	39.00 ± 1.15 bc
Pertiwi 3 flour	182.33 ± 2.01 e	148.00 ± 4.73 d	75.67 ± 10.86 cd	64.00 ± 13.04 cd
Bisi 18 flour	120.33 ± 4.02 cd	91.67 ± 3.50 b	33.33 ± 2.99 ab	25.33 ± 1.84 ab
Bisma flour	107.00 ± 3.00 c	81.00 ± 2.52 b	29.33 ± 1.26 ab	23.67 ± 1.95 ab

Note: The mean at the same column followed by the same letters are not significantly different ($p < 0.05$)

Table 5. Developmental period of *Tribolium castaneum* on five corn varieties in whole grain and flour form

Treatments	Developmental period (days) ($\bar{X} \pm SE$)				
	Egg	Larva	Pupa	Egg-adult	Life cycle
Pioneer 21 whole grain	5.70 ± 0.21 ab	27.83 ± 0.05 e	6.43 ± 0.02 c	39.97 ± 0.08 ef	47.00 ± 0.33 c
Pioneer 29 whole grain	5.83 ± 0.08 bc	27.87 ± 0.11 e	6.43 ± 0.04 c	40.13 ± 0.19 f	48.30 ± 0.33 cd
Pertiwi 3 whole grain	5.90 ± 0.03 bc	27.73 ± 0.04 de	6.43 ± 0.07 c	40.07 ± 0.14 f	48.43 ± 0.19 d
Bisma 18 whole grain	6.03 ± 0.04 c	27.77 ± 0.04 de	6.43 ± 0.04 c	40.23 ± 0.04 fg	48.56 ± 0.38 d
Bisma whole grain	6.13 ± 0.05 c	27.97 ± 0.04 e	6.43 ± 0.05 c	40.63 ± 0.13 g	49.13 ± 0.19 d
Pioneer 21 flour	5.50 ± 0.06 a	26.77 ± 0.02 a	5.97 ± 0.02 a	38.23 ± 0.05 a	41.87 ± 0.19 a
Pioneer 29 flour	5.67 ± 0.08 ab	27.20 ± 0.12 bc	6.10 ± 0.03 ab	38.97 ± 0.02 bc	42.73 ± 0.19 a
Pertiwi 3 flour	5.50 ± 0.03 a	27.03 ± 0.05 ab	6.10 ± 0.03 ab	38.63 ± 0.02 ab	42.77 ± 0.19 a
Bisi 18 flour	5.83 ± 0.04 bc	27.23 ± 0.02 bc	6.17 ± 0.02 b	39.23 ± 0.04 cd	44.20 ± 0.00 b
Bisma flour	5.83 ± 0.05 bc	27.50 ± 0.00 cd	6.20 ± 0.03 b	39.53 ± 0.02 de	45.50 ± 0.33 b

Note: The mean at the same column followed by the same letters are not significantly different ($p < 0.05$)

Table 6. Grain characteristics of five corn varieties

Physicochemical characteristics	Corn varieties				
	Pioneer 21	Pioneer 29	Pertiwi 3	Bisi 18	Bisma
Protein (%)	8.86	6.99	8.83	6.88	6.48
Fat (%)	4.44	4.99	3.83	3.45	4.64
Water (%)	12.11	12.97	14.65	10.78	9.45
Ash (%)	1.26	1.18	1.37	1.21	1.30
Carbohydrate (%)	73.33	73.87	71.32	77.68	78.13
Hardness level	277.36	401.80	275.17	403.14	262.46

Preference, growth, and development of *T. castaneum* is influenced by physical and chemical factors. The physical factors that affect preference, growth, and development of *T. castaneum* are the form and the hardness of feed, while the chemical factors are feed nutrition and volatile compound on feed. The physical forms of feed used in this study were whole grain and flour, and the chemical aspect tested was proximate analysis. This study revealed a negative correlation between the grain hardness and the number of eggs ($r = -0.759$), the number of larvae ($r = -0.711$), the number of pupae ($r = -0.785$), and the number of F1 progeny emerged ($r = -0.826$) (Table 7). These results mean that the softer grain resulting in the more insect growth. Corn seeds that have high hardness levels can inhibit *T. castaneum* adults and larvae feeding activity. The higher hardness of corn seeds will express the lower number of eggs, larvae, pupae, and F1 progeny emerged. Astuti et al. (2013) stated that the hardness level of seeds was negatively correlated to the number of eggs and F1 progeny emerged of *Rhyzopertha dominica*. This resulting study showed that Bisi 18 was less preferred by *T. castaneum* because it has higher hardness levels than others i.e. 403.14 (Table 6).

Tribolium castaneum more preferred to feed and lay eggs on high nutritional quality of feeds (Abushama and Jeraiwi 1987; Bostan and Naeem 2002; Javed et al. 2016). The low nutritional quality of feed can inhibit some insect activities especially for feeding and laying eggs to support the growth and development of *T. castaneum* (Turaki et al. 2007; Chapman 2013). However, there was no correlation found between protein, fat, ash, water, and carbohydrate content with the number of eggs, larvae, pupae, and F1 progeny emerged. This indicated that the chemical content on various types of varieties did not affect the preference level of *T. castaneum*. This insect was more preferred with the physical characteristic of feed, not only the form but also the hardness of kernels. Pioneer 21 corn variety has higher protein content than Pioneer 29, Pertiwi 3, Bisi 18, and Bisma (Table 6). This showed that protein content on feed affected the preference, growth, and development of *T. castaneum* insects. High protein content on feed causes greater preference, growth, and development of *T. castaneum* insects compared to the feed which has low protein content. This was in accordance with Khair (2002), Kayode et al. (2014), and Sarwar (2015) that stated the preferences, growth, and development of *T. castaneum* insects are greater on high protein content feed. Furthermore, a report by Wong and Lee (2011) show that adult beetles of *T. castaneum* more emerged on the high protein content diet, however, it was fewer number of adult and longer adult development on high carbohydrate content diet because it may be toxic.

The highest population growth of *T. castaneum* was on Pioneer 21 flour, even though adult insect mortality was not significantly different among all treatments. This indicated that *T. castaneum* still could feed on whole grain though it was more difficult than on corn-flour. In addition, Zakka et al. (2013) also stated that adult mortality of *T. castaneum* was not significantly different in both whole

grain and flour form, but the population growth of this insect was higher on flour form.

In conclusion, the highest preference, population growth, and development of *T. castaneum* are on Pioneer 21 variety in flour form. The most influential factor of its preference and biology is the physical characteristics both in form and hardness level of kernels. However, the chemicals content of different varieties in the same type of commodity does not affect the preference, population growth, and development of *T. castaneum*.

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